REMARKS

Applicants have carefully considered the Examiner's remarks and have amended the claims to more clearly set forth the invention. By this Amendment E, claims 2, 3, and 5 have been amended, and new claims 20-22 have been added. Thus, claims 1-10 and 19-22 are now pending in the application. As explained in detail below, the pending claims are believed to be in condition for allowance.

Claims 1, 2, and 19 stand rejected under 35 U.S.C. 102(b) as being unpatentable over U.S. Patent No. 4,876,438 to Watanabe et al. (Watanabe). Applicants submit, however, that Watanabe fails to teach each and every aspect of the claimed invention.

Watanabe discloses a conventional control loop configuration for controlling the diameter of monocrystalline rod, such as illustrated as prior art in FIG. 9 of the present application, with the exception of the use of second integration. In general, the cited patent teaches a configuration of PID loops that eliminates steady-state diameter error by using a second integrator. Those skilled in the art are familiar with this second integration method, which was part of a commercial control system (Hamco/Kayex 6000) in use since the mid-1980's. Moreover, the Watanabe patent merely refers to slow disturbances that can be handled by integral and integral squared control only. Typical slow disturbances include crucible and heater changes during and between crystals (col. 8, lines 41-43), fixing the crucible position, which results in lowering the interface (col. 8, lines 56-62), and some type of "a continuous disturbance" (col. 9, lines 16-26). Watanabe refers to this type of disturbance in the singular and implies no change in magnitude, as would be the result of following a continuously varying velocity profile. In fact, Watanabe teaches away from responding to fast disturbances by ignoring proportional and derivative control in simplifying its control equations (e.g., col. 9, equation 2 versus col. 8 equation 1). The melt temperature and diameter response to power changes in Watanabe follow a conventional response such as the one shown in FIG. 11 of the present application. Further, applicants note the "differential equations" (equations 1-4) cited by the Examiner represent only the PID transfer

functions and not the melt itself. Indeed, the tuning of PID loops is normally performed when the process transfer function (or model) is unknown.

As acknowledged by the Examiner, Watanabe discloses a control system in which the velocity or pull rate at which the ingot is lifted from the melt is constant during the straight body portion of the ingot. See Office action at page 2. In contrast, applicants claim pulling the crystal from the melt ***according to a velocity profile***. The Examiner's determination that lifting an ingot at a constant speed reads on pulling the ingot from the melt according to a velocity profile fails to appreciate the difference between a substantially fixed, constant value velocity as disclosed by Watanabe and the velocity profile as disclosed by applicants.

FIG. 4 of the present application illustrates an exemplary velocity profile of the present invention. The velocity profile defines a target pull rate as a function of the length of crystal during the pull. See application, page 14, lines 10-11. According to applicants' invention, the target pull velocity of the ingot during the body portion need not be a constant velocity, but rather may continually change as a function of ingot length, such as shown in FIG. 4. In contrast to applicants' invention, Watanabe merely discloses that the pull velocity is constant during the manufacture of the straight body portion of the rod. Those skilled in the art recognize that "locked on" or constant seed lift diameter control is not very robust against disturbances without the use of the melt model with pulsing power control method and constant Vc is not adequate to achieve the velocity profile needed for perfect silicon (e.g., FIG. 4 of the present application) or other desired growth conditions.

Further, it is widely known that a change in Vc is a near-instantaneous disturbance to diameter control that must be corrected by accurately (and quickly) adjusting the melt temperature. See application, page 18, lines 9-13. As explained above, the melt temperature and diameter response to power changes in Watanabe follow a conventional response such as the one shown in FIG. 11 of the present application. In contrast, the present invention involves the novel response of FIG. 12. Watanabe teaches away from this aspect of the invention for achieving

diameter control as expressed in claim 1 by "pulling the ingot from the melt at a pull rate following a target pull rate defined by a velocity profile."

For these reasons, applicants submit pulling at a constant velocity as set forth in the cited art teaches away from determining a power set point as a function of diameter error in combination with pulling the ingot as a function of the velocity profile of the present invention independently of diameter error and, thus, the Watanabe reference fails to teach or suggest each and every feature of claim 1.

Another significant distinction between the present invention and the cited reference is the method in which the power supplied to the heater is adjusted. Watanabe discloses that an error signal representing the difference between the crystal diameter set point and the process diameter variable is provided to a PID controller and an I^2 controller. The output of the controllers and the output of a predetermined power supply setter are added together and supplied to a heater drive circuit for adjusting the melt temperature to control diameter of the monocrystalline rod. See col. 8, lines 25-35. As shown in FIG. 10, the present invention discloses providing an error signal representing the difference between the crystal diameter set point and process diameter variable to a PID loop. The output of the PID loop is received by a ***temperature model*** that outputs a heater power supply set point to effect desired changes in the crystal diameter. The Examiner asserts that the described control of the diameter by power adjustments requires an inherent definition of the temperature model in response to power fluctuations and the resultant effect on ingot diameter. See Office action page 2. Nevertheless, as described below, Wantanabe fails to teach or suggest a temperature model that estimates the relationship between heater power and the temperature of the surface of silicon melt, and that ***supplies power having a magnitude greater than a steady state power*** to achieve the desired melt temperature changes. See application page 23, lines 8-10.

As described in the present application, the diameter response time for temperature changes is typically much slower than the response time for pull rate changes. For example, a step change in pull rate typically achieves a diameter response in seconds whereas a step change

in heater power or melt temperature results in a much more sluggish response taking tens of minutes to achieve an equivalent effect. See application page 3, lines 19-23. FIG. 11 illustrates an exemplary temperature response for a conventional control scheme such as shown in FIG. 9 (e.g., Watanabe), and FIG. 12 illustrates an exemplary temperature response for a control scheme of the present invention. FIGS. 11 and 12 provide a comparison of the step response and a pulse response. As discussed above, with the exception of second integration, the Watanabe patent discloses a conventional step response control scheme such as shown in FIG. 11. That is, Watanabe discloses a system that employs steady state power changes with a second integrator to eliminate steady state diameter error (e.g., hunting). In contrast, the present invention discloses a control system in which ***a pulse of power*** having a predetermined amplitude and duration ***followed by a steady state power change*** is used to decrease the amount of time required to achieve a desired diameter. See application, page 21, lines 15-18. For example, as shown in FIG. 12 the heater output rises relatively rapidly due the ***power pulse*** input and achieves the desired magnitude in a fraction of the time that it takes output of FIG. 11 to reach the desired magnitude.

To this end, new claim 20 recites, in part, "determining power to apply to the heater; said determined amount of power ***having an amplitude greater than a steady state power amplitude***," and "adjusting the power supplied to the heater according to the determined power thereby changing the temperature of the melt to control the diameter of the ingot." Further, amended claim 2 and new claim 21 recite "determining the power includes ***calculating a pulse of power*** to apply to the heater, said power pulse having an amplitude greater than the steady state power". Applicants submit that Watanabe is silent as to applying power, particularly a pulse of power, having amplitude greater than the steady state power to the heater, or pulling the ingot according to the velocity profile as described in the present invention. Thus, Watanabe fails to teach or suggest each and every element of the claimed invention.

Claims 3-10 are also rejected under 35 U.S.C. 103(a) as being unpatentable over Watanabe. However, for substantially the same reasons Watanabe fails to teach or suggest every

element of claim 1, Watanabe fails to teach or suggest every aspect of the inventions of these claims. Particularly, applicants submit that Watanabe in no way teaches or suggests, a temperature model that estimates the relationship between heater power and the temperature of the surface of silicon melt, and that calculates an amount of power (e.g., power pulses) having an amplitude greater than the steady state power to apply to the heater in order to reduce the amount of time required to achieve desired melt temperature changes. As a result, applicants' invention enables efficient and accurate diameter control that achieves a desired temperature faster, and, thus, achieves a desired diameter faster.

The Examiner's assertion that it would have been obvious to one of ordinary skill in the art to optimize the differential equation model of the diameter control by power adjustment (Office action at page 3) is clearly based on improper hindsight reasoning. Applicants recognize that a judgment on obviousness is in a sense necessarily a reconstruction based on hindsight reasoning, and is proper so long as it takes into account only knowledge that was in the level of ordinary skill in the art at the time the claimed invention was made. In re McLaughlin, 443 F.2d 1392, 1395 (CCPA 1971.) Nevertheless, such reconstruction cannot include knowledge gleaned only from applicants' disclosure. Id. As discussed above, Watanabe merely shows a method in which the power adjust would provide a temperature response such as illustrated in FIG. 11 of the present application. There is nothing in Watanabe that discloses or suggests determining a power set point as a function of diameter error in combination with pulling the ingot as a function of a varying velocity profile independently of diameter error. Moreover, the cited art is silent as to applying power pulses to obtain the improved temperature response such as illustrated in FIG. 12 of the present application. Thus, the Examiner's conclusion that would have been obvious to one of ordinary skill in the art to optimize the differential equation model of the diameter control by power adjustment is gleaned solely from applicants' disclosure and constitutes improper hindsight analysis.

Moreover, if "a proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to

make the proposed modification." In re Gordon, 733 F.2d 900 (Fed. Cir. 1984). Pulling a crystal according to the velocity profile of the present invention would render the reference inoperable because, as disclosed in Watanabe, the length of the ingot is determined by time integrating the lifting speed of the monocrystal ingot. See col. 8, lines 6-15. Thus, modifying Watanabe such that the ingot is lifted according to the velocity profile of the present invention would result in an error in length calculation because the velocity of the present invention is not a function of time as required by Watanabe, but rather a function of length.

For these reasons, applicants submit that independent claims 1 and 20 are allowable over the cited art. Claims 2-10, and 19 depend from claim 1 and are believed to be allowable for at least the same reasons as claim 1. Claims 21 and 22 depend from claim 20 and are believed to be allowable for at least the same reasons as claim 20.

It is believed that a full and complete response has been made to the Office action and, as such, the application is in condition for allowance. Such allowance is hereby respectfully requested.

The Commissioner is hereby authorized to charge any fees that may be required during the entire pendency of this application to Deposit Account No. 19-1345.

Respectfully submitted,

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